AMENDMENTS TO THE SPECIFICATION AND ABSTRACT

Please replace the paragraph beginning at line 4 on page 7 with the following rewritten paragraph:

[0012] The term "extinction ratio" as used herein refers to a ratio which indicates the power of light of a desired wavelength to be outputted at one output position with respect to the power of light of a wavelength to be cut off at the same output position. Note that Documents 2 through 4 present the concept of the "ratio between powers of light" (i.e., the "contrast" or the "extinction ratio~~)~~"_)_ which indicates a ratio between powers of light at the same wavelength in different output positions. Thus, the concept as presented by Documents 2 through 4 is completely different from the concept of the extinction ratio as described herein which indicates the ratio between powers of light of different wavelengths in the same output position.

Please replace the paragraph beginning at line 15 on page 33 with the following rewritten paragraph:

[0073] Further still, ~~In~~ in the multi-mode propagation portion having such an optical path length as to cause a difference between θ_1 and θ_2 to be in the range of $m\pi\pm\pi/2$ and having such a width as to vary along a direction of an optical axis of the optical demultiplexer, mode interference of the shorter wavelength is caused to occur first, thereby making it possible to make the optical demultiplexer more compact.

Please replace the paragraph beginning at line 12 on page 35 with the following rewritten paragraph:

[0083] FIG. 1 is a diagram schematically illustrating the structure of an optical demultiplexer 100a according to a first embodiment of the present invention;

FIG. 2A illustrates a simulation result obtained by a beam propagation method (BPM) which shows how light of a wavelength of 1.30 μm is separated in the optical demultiplexer 100a illustrated in FIG. 1;

FIG. 2B illustrates a BPM simulation result showing how light of a wavelength of 1.55 μm is separated in the optical demultiplexer 100a illustrated in FIG. 1;

FIG. 3A illustrates a BPM simulation result showing a detailed distribution of the power of light of a wavelength propagating through a multi-mode waveguide 102a;

FIG. 3B illustrates a BPM simulation result showing a detailed distribution of the power of light of another wavelength propagating through the multi-mode waveguide 102a;

FIG. 4 is a graph used for describing that a phase difference in movement between powers of light is set so as to become substantially an integral multiple of π;

FIG. 5 is a graph illustrating a distribution of the power of light at output positions of the multi-mode waveguide 102a;

FIG. 6 is a diagram schematically illustrating the structure of an optical demultiplexer 100b according to a third embodiment of the present invention;

FIG. 7 is a diagram schematically illustrating the structure of an optical demultiplexer 100c according to a fourth embodiment of the present invention;

FIG. 8 is a diagram schematically illustrating the structure of an optical demultiplexer 100d according to a fifth embodiment of the present invention;

FIG. 9 is a diagram schematically illustrating the structure of the optical demultiplexer 101d illustrated in FIG. 8 to which a dummy single-mode waveguide is connected;

FIG. 10 is a diagram schematically illustrating the structure of an optical demultiplexer 100e according to a sixth embodiment of the present invention;

FIG. 11 is a diagram schematically illustrating the structure of an optical demultiplexer 100f according to a seventh embodiment of the present invention;

FIG. 12 is a diagram schematically illustrating the structure of an optical demultiplexer 101f including n parallel single-mode waveguides $122_{f\text{-}1}$ through $122_{f\text{-}n}$, instead of including a multi-mode waveguide 102f of the optical demultiplexer 100f according to the seventh embodiment;

FIG. 13 is a diagram schematically illustrating the structure of an optical demultiplexer 100g according to an eighth embodiment of the present invention;

FIG. 14 is a diagram schematically illustrating the structure of an optical demultiplexer 101a in an exemplary case where a refractive index of a multi-mode propagation portion is changed by applying an electro-optic effect;

FIG. 15 is a diagram schematically illustrating the structure of an optical demultiplexer 102a in an exemplary case where a refractive index of a multi-mode propagation portion is changed by applying a thermo-optic effect;

FIG. 16 is a diagram schematically illustrating the structure of an optical multiplexer 200a according to a ninth embodiment of the present invention;

FIG. 17 is a diagram schematically illustrating the structure of an optical multiplexer 200b according to a tenth embodiment of the present invention;

FIG. 18 is a diagram schematically illustrating the structure of an optical multiplexer 200c according to an eleventh embodiment of the present invention;

FIG. 19 is a diagram schematically illustrating the structure of an optical multiplexer 200f according to a twelfth embodiment of the present invention;

FIG. 20 is a diagram schematically illustrating the structure of an optical multiplexer 201f including a high-order multi-mode propagation portion 213f consisting of n single-mode waveguides 223f;

FIG. 21 is a diagram schematically illustrating the structure of an optical multiplexer 210a in an exemplary case where a refractive index of a multi-mode propagation portion is changed by applying an electro-optic effect;

FIG. 22 is a diagram schematically illustrating the structure of an optical multiplexer ~~202a~~ 220a in an exemplary case where a refractive index of a multi-mode propagation portion is changed by applying a thermo-optic effect;

FIG. 23 is a diagram schematically illustrating the structure of a WDM gain adjuster 300a according to a thirteenth embodiment of the present invention;

FIG. 24 is a diagram illustrating the structure of a WDM add/drop 300b according to a fourteenth embodiment of the present invention;

FIG. 25 is a diagram schematically illustrating a WDM transmitter/receiver module 300c according to a fifteenth embodiment of the present invention;

FIG. 26 is a diagram schematically illustrating a WDM interleaver 300d according to a sixteenth embodiment of the present invention;

FIG. 27 is a diagram schematically illustrating the structure of a WDM interleaver 300e according to a seventeenth embodiment of the present invention;

FIG. 28 is a graph illustrating wavelength characteristics of a transmission/cut-off loss in a former-stage demultiplexing portion;

FIG. 29 is a graph illustrating wavelength characteristics of a transmission/cut-off loss in a latter-stage demultiplexing portion; and

FIG. 30 is a graph illustrating wavelength characteristics of a transmission/cut-off loss in the entire optical demultiplexer according to an eighteenth embodiment of the present invention.

Please replace the heading at line 17 on page 39 with the following rewritten heading:

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Please replace the paragraph beginning at line 2 on page 42 with the following rewritten paragraph:

[0092] The V-groove 105a is formed in the substrate 106a in order to align and connect a single-mode input optical fiber 7 with the input end of the single-mode input waveguide 101. The V-groove 115a is formed in the substrate 106a in order to align and connect a first single-mode output optical fiber 8 with the output end of the first single-mode output waveguide ~~3~~103a. The V-groove 125a is formed in the substrate 106a in order to align and connect a second single-mode output optical fiber 9 with the output end of the second single-mode output waveguide 104a.

Please replace the paragraph beginning at line 4 on page 45 with the following rewritten paragraph:

[0099] Accordingly, in the case of the optical demultiplexer 100a, the optical path length of the multi-mode waveguide 102a is determined such that the first output waveguide 103a, which guides light of a wavelength of 1.30 μm, and the second output waveguide 104a, which guides light of a wavelength of 1.55 μm, are provided in the vicinity of the location at which light of wavelengths of 1.30 μm and 1.55 μm is separated into light of a wavelength of 1.30 μm and light of a wavelength of 1.55 μm. As described ~~later~~below, the first and second output waveguides 103a and 104a are connected to the output end of the multi-mode waveguide 102a at positions X_1 and X_2, respectively. By determining the optical path length of the multi-mode waveguide 102a as described above, it is made possible to allow the optical demultiplexer 100a simply structured with the waveguides to separate the light of wavelengths of 1.30 μm and 1.55 μm into light of a wavelength of 1.30 μm and light of a wavelength of 1.55 μm.

Please replace the paragraph beginning at line 20 on page 45 with the following rewritten paragraph:

[0100] Next, a detailed description is provided as to how the optical length of the multi-mode waveguide 102a is determined. FIGs. 3A and 3B are diagrams representing BPM simulation results showing a detailed distribution of the powers of light of wavelengths of 1.30 μm and 1.55 μm propagating through the multi-mode waveguide 102a. Specifically, in FIG. 3A, distribution of the power of light of a wavelength of 1.30 μm is shown, while in FIG. 3B, a distribution of the power of light of a wavelength of 1.55 μm is shown.

Please replace the paragraph beginning at line 19 on page 47 with the following rewritten paragraph:

[0104] Similar to the light of a wavelength of 1.30 μm, as shown in FIG. 3B, the power of light of a wavelength of 1.55 μm propagating through the multi-mode waveguide 102a is caused by the mode interference to vary such that maximum and minimum values of the power of light alternately appear on two straight lines, i.e., a second 1.55 μm light power variation line which passes a multi-mode waveguide output end point P_{2a} so as to be parallel to the center line 112a, and a first 1.55 μm light power variation line which passes point P_{2b} symmetric to P_{2a}~~P_{2b}~~ with respect to the center line 112a so as to be parallel to the center line 112a. Moreover, the power of light varies across the two straight lines such that the maximum and minimum values are inversely-correlated with each other. Accordingly, the power of the light of a wavelength of 1.55 μm appears as if it propagates through the multi-mode waveguide 102a while moving alternately on the two straight lines. In this case, $P_{1a} \neq P_{2b}$ and $P_{2a} \neq P_{1b}$. The reason for this is that spreading distribution in the width direction of the multi-mode waveguide 102a differs between the wavelengths, and the longer wavelength spreads wider.

Please replace the paragraph beginning at line 2 on page 51 with the following rewritten paragraph:

[0116] As described above, in the first embodiment, in the case where a phase difference between the zero- and first-order modes at a wavelength of 1.30 μm is θ_1 and a phase difference

between the zero- and first-order modes at a wavelength of 1.55 μm is θ_2, the multi-mode waveguide 102a has such an optical path length as to cause a difference between θ_1 and θ_2 to become substantially an integral multiple of π. Further, the input waveguide is connected to the multi-mode waveguide 102a in such a position that the optical axis thereof becomes offset from the center line 112a of the multi-mode waveguide 102a, and the first and second output waveguides 103a and 104a are provided in opposite positions with respect to the center line ~~102a~~112a. Thus, it is possible to separate light of wavelengths of 1.30 μm and 1.55 μm. The optical demultiplexer according to the first embodiment is simply structured with the multi-mode optical waveguide, and therefore can be provided at low cost.

Please replace the paragraph beginning at line 8 on page 52 with the following rewritten paragraph:

[0120] For example, the shape of the multi-mode waveguide can be optimized by optimizing lengths of three sides of a rectangular solid along an optical axis or optimizing a distance between opposed side faces in directions toward which light is separated, so as to change along the optical axis~~"~~.

Please replace the paragraph beginning at line 21 on page 68 with the following rewritten paragraph:

[0157] Further, by narrowing the first multi-mode region 112c as compared to the second multi-mode region 122c, a larger phase difference can be obtained in the second multi-mode region ~~112c~~122c.

Please replace the paragraph beginning at line 12 on page 72 with the following rewritten paragraph:

[0169] In FIG. 10, the optical demultiplexer 100e includes: an input waveguide 101a; a multi-mode propagation portion 102e having a plurality of stages; a first output waveguide 103a; a second output waveguide 104a; a substrate 106e for securing the above waveguides; and V-grooves 105a, 115a, and 125a. The multi-mode propagation portion 102e includes a first multi-mode region 152e and a second multi-mode propagation portion 162e. The first multi-mode region 152e includes a first single-mode ~~region~~ waveguide 112e and a second single-mode

waveguide 122e. The second multi-mode region 162e includes a third single-mode ~~region~~ waveguide 132e and a fourth single-mode waveguide 142e.

Please replace the paragraph beginning at line 23 on page 72 with the following rewritten paragraph:

[0170] The first and second single-mode waveguides 112e and 122e included in the first multi-mode region 152e are arranged in parallel with each other at the input side of the multi-mode propagation portion 102e, and are spaced apart from each other by a distance of less than 20 μm. In a strict sense, the ~~second~~ first single-mode waveguide ~~122e~~ 112e is not entirely parallel with the second single-mode waveguide 122e since an output side portion ~~thereof~~ of the second single-mode waveguide 122e is curved so as to connect to the fourth single-mode waveguide 142e.

Please replace the paragraph beginning at line 7 on page 73 with the following rewritten paragraph:

[0171] The third and fourth single-mode waveguides 132e and 142e included in the second multi-mode region 162e are arranged in parallel with each other, and are spaced apart from each other by a distance less than or equal to 20 μm and longer than the distance between the first and second single-mode waveguides 112e and 122e. In a strict sense, the fourth single-mode waveguide 142e is not entirely parallel with the third single-mode waveguide 132e since an input side portion ~~thereof~~ of the fourth single-mode waveguide 142e is curved so as to connect to the second single-mode waveguide 122e.

Please replace the paragraph beginning at line 18 on page 76 with the following rewritten paragraph:

[0182] In the multi-mode waveguide 102f, ~~Similar~~ similar to the light of the k'th wavelength λ_k, the light of the k+1'th wavelength λ_{k+1} is divided into light under the zero- to n-1'th-order modes characteristic of the multi-mode waveguide 102f. Due to modal dispersion among the zero- to n-1'th-order modes, the light of the k+1'th wavelength λ_{k+1} propagates through the multi-mode waveguide 102f, such that the power of the light moves sequentially on n parallel straight lines in accordance with a certain propagation coefficient. Note that the n

parallel straight lines passes a connecting position of the k+1'th output waveguide $103_{f\text{-}k+1}$ to the multi-mode waveguide 102f.

Please replace the paragraph beginning at line 7 on page 87 with the following rewritten paragraph:

[0209] In the multi-mode waveguide 203a, light of a wavelength of 1.30 μm, which has entered the first input waveguide 201a via the first input optical fiber 28, is divided into light under the zero- and first-order modes. Similarly, in the multi-mode waveguide 203a, light of a wavelength of 1.55 μm, which has entered the second input waveguide 202a via the second input optical fiber 29, is divided into light under the zero- and first-order modes. Due to mode interference caused in the multi-mode waveguide 203a, both the powers of the light of wavelengths of 1.30 μm and 1.55 μm are maximized at the output end of the multi-mode waveguide 203a (i.e., the input end of the output waveguide 204a). Wavelength-multiplexed light obtained by the output waveguide 203a is inputted to the output optical fiber ~~207e~~ 27 via the output waveguide ~~204e~~204a.

Please replace the paragraph beginning at line 11 on page 90 with the following rewritten paragraph:

[0217] As described above, the tenth embodiment uses the multi-mode waveguide 203b having an optical length, which can be less than or equal to 5000 μm as described in the ~~thirds~~ third embodiment, whereby it is possible to provide a compact optical multiplexer.

Please replace the paragraph beginning at line 19 on page 91 with the following rewritten paragraph:

[0222] The second multi-mode region 223c has a characteristic similar to that of the first multi-mode region ~~102e~~ 112c of the multi-mode waveguide 102c included in the optical demultiplexer 100c according to the fourth embodiment. That is, the second multi-mode region 223c causes mode interference of only light of a wavelength of 1.30 μm, such that the power of such light is maximized at the output end face (i.e., the input end of the output waveguide 204a).

Please replace the paragraph beginning at line 24 on page 96 with the following rewritten paragraph:

[0243] Alternatively, the gain of each wavelength may be monitored in the multiplexing section ~~306a~~302a. In this case, a correction value is fed back to the gain adjusting section 303a until the output of the multiplexing section ~~306a~~ 302a reaches a desired gain level. In such a case, an external control section and a monitor section may be provided outside the multiplexing section ~~306a~~ 302a in order to control each gain adjusting section 303a.

Please replace the paragraph beginning at line 9 on page 97 with the following rewritten paragraph:

[0245] Further, the multi-mode waveguide 102f of the demultiplexing section 301a and the multi-mode waveguide 203f of the multiplexing section ~~306a~~ 302a may be formed by n parallel single-mode waveguides.

Please replace the paragraph beginning at line 10 on page 99 with the following rewritten paragraph:

[0252] Further, the input and output optical fibers 7 and 27 may be configured so as to be mutually connected in a loop.

Please replace the paragraph beginning at line 13 on page 104 with the following rewritten paragraph:

[0268] In this manner, the multi-mode waveguide ~~301~~ 301d has such an optical path length as to cause the powers of the odd-numbered wavelength light and the even-numbered wavelength light to be separated onto the two parallel straight lines, and the first and second output waveguides 103a and 104a are provided in the vicinity of the location at which the odd-numbered wavelength light and the even-numbered wavelength light are separated. This allows even a WDM interleaver simply structured with waveguides to readily separate the odd-numbered wavelength light and the even-numbered wavelength light.

Please replace the paragraph beginning at line 23 on page 104 with the following rewritten paragraph:

[0269] Note that as in the case of the optical demultiplexer 100d (FIG. 8), the multi-mode waveguide ~~301~~ 301d may be formed by two parallel single-mode waveguides.

Please replace the paragraph beginning at page line 15 on 106 with the following rewritten paragraph:

[0274] The first latter-stage multi-mode waveguide 304e is a second interleaver having an optical path length such that a phase difference in movement between the powers of light of a 4k-3'th wavelength λ_{4k-3} (hereinafter, referred to as the "4k-3'th multiplexed wavelength light") and light of a 4k-1'th wavelength λ_{4k-1} (hereinafter, referred to as the "4k-1'th multiplexed wavelength light") becomes substantially an integral multiple of π.

Please replace the paragraph beginning at line 23 on page 106 with the following rewritten paragraph:

[0275] The second latter-stage multi-mode waveguide 307e is a third interleaver having an optical path length such that a phase difference in movement between the powers of light of a 4k-2'th wavelength λ_{4k-2} (hereinafter, referred to as the "4k-2'th multiplexed wavelength light") and light of a 4k'th wavelength λ_{4k} (hereinafter, referred to as the "4k'th multiplexed wavelength light") becomes substantially an integral multiple of π.

Please replace the paragraph beginning at line 18 on page 108 with the following rewritten paragraph:

[0282] Since the refractive indices of the multi-mode waveguides 301e, 304e, and 307e are in linear relationship with a wavelength in the range of use, the multi-mode waveguides 304e and ~~305e~~ 307e can have an equal optical path length.